



# Photocatalytic Conversion of CO<sub>2</sub> on Mars

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## Introduction

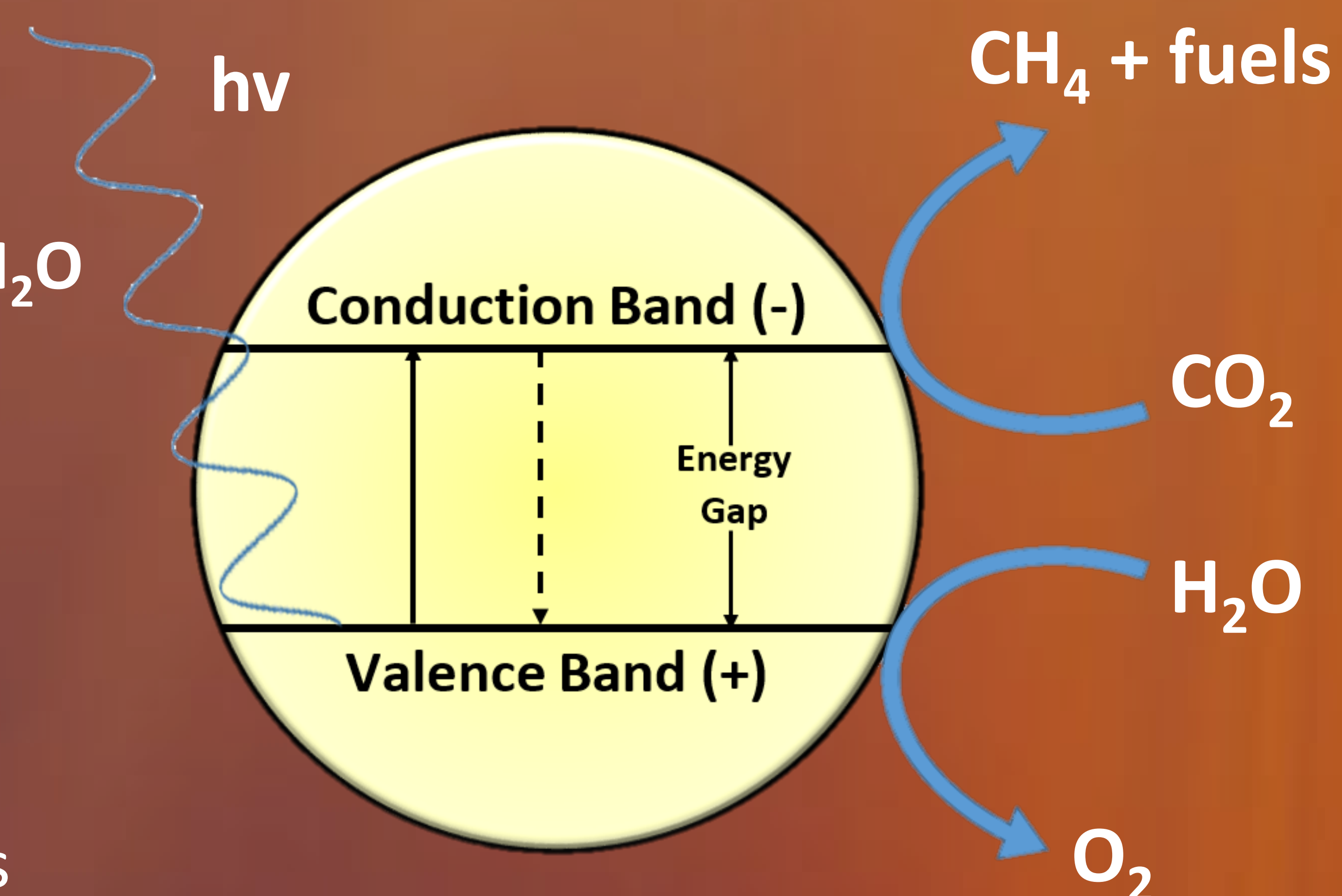
Light on Mars shows potential for providing the energy means necessary for enhanced **In-Situ Resource Utilization (ISRU)**. Through photocatalysis, the energy barrier required to convert CO<sub>2</sub> is lowered and CH<sub>4</sub> production is favorable.

### General Reaction Mechanism

- (1)  $\text{CO}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{HCOOH}$
- (2)  $\text{HCOOH} + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{HCHO} + \text{H}_2\text{O}$
- (3)  $\text{HCOH} + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{CH}_3\text{OH}$
- (4)  $\text{CH}_3\text{OH} + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{CH}_4 + \text{H}_2\text{O}$

### Photocatalyst Requirements

- High CH<sub>4</sub> selectivity
- Utilize H<sub>2</sub>O as a reducing agent
- Convert CO<sub>2</sub> at low temperatures
- Activate under ultraviolet and visible light (UV-Vis)



## Material Characterization

### Scanning Electron Microscopy (SEM)

- Detailed imaging of nanoparticles



### Transmission Electron Microscopy (TEM)

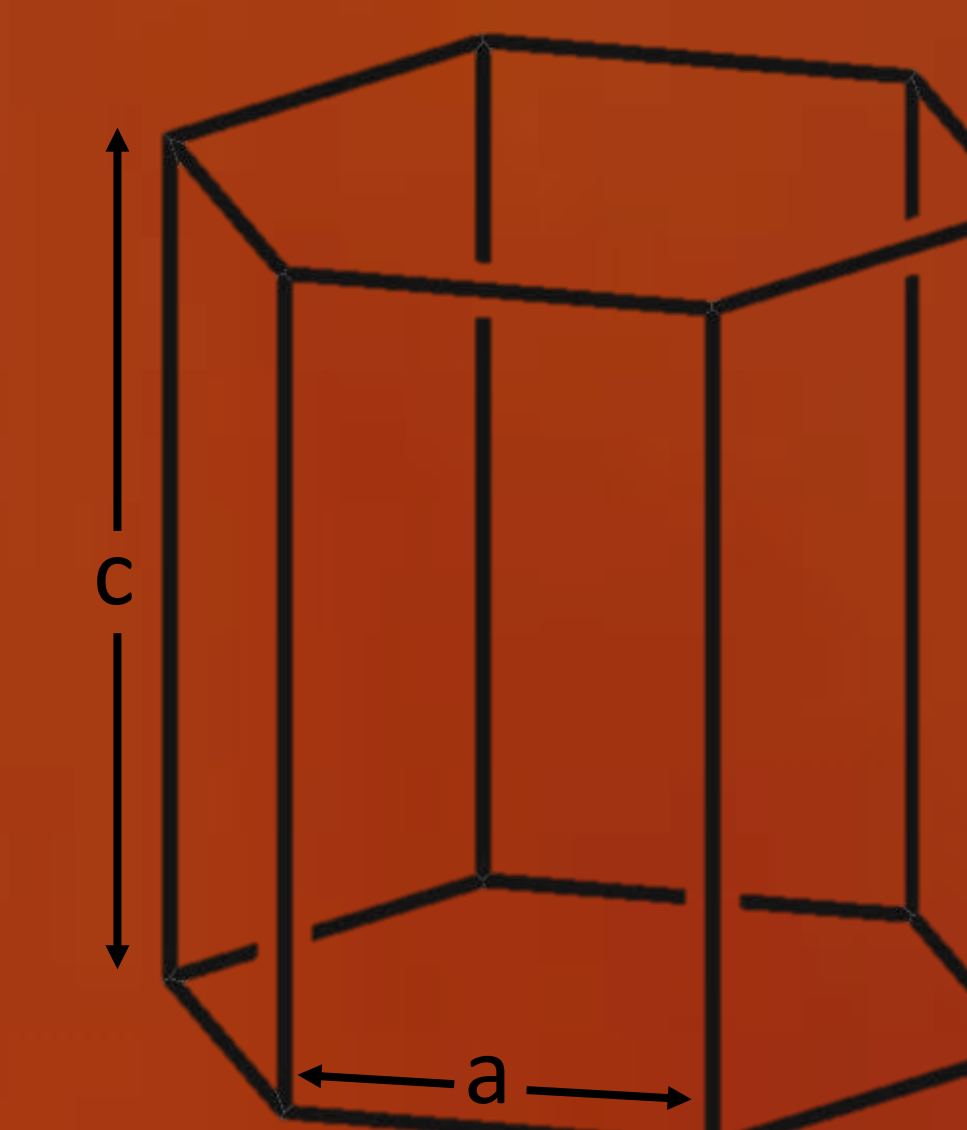
- Detailed imaging of crystalline structures

Hexagonal MoS<sub>2</sub> within flake (by GRC)



### X-Ray Diffraction (XRD)

- Lattice parameter calculation



MoS <sub>2</sub> Cell Parameter	Value
a	3.15 Å
c	18.32 Å
Cell Volume	158.5 Å <sup>3</sup>

## Catalysts of Interest

### Transition Metal Dichalcogenides (TMDs)

- MoS<sub>2</sub> • MoSe<sub>2</sub> • WS<sub>2</sub> • WSe<sub>2</sub>
- Solid powders and thin layer films used for catalysis exhibit ideal band gap for CO<sub>2</sub> reduction

### Synthesis via Chemical Vapor Deposition (CVD)

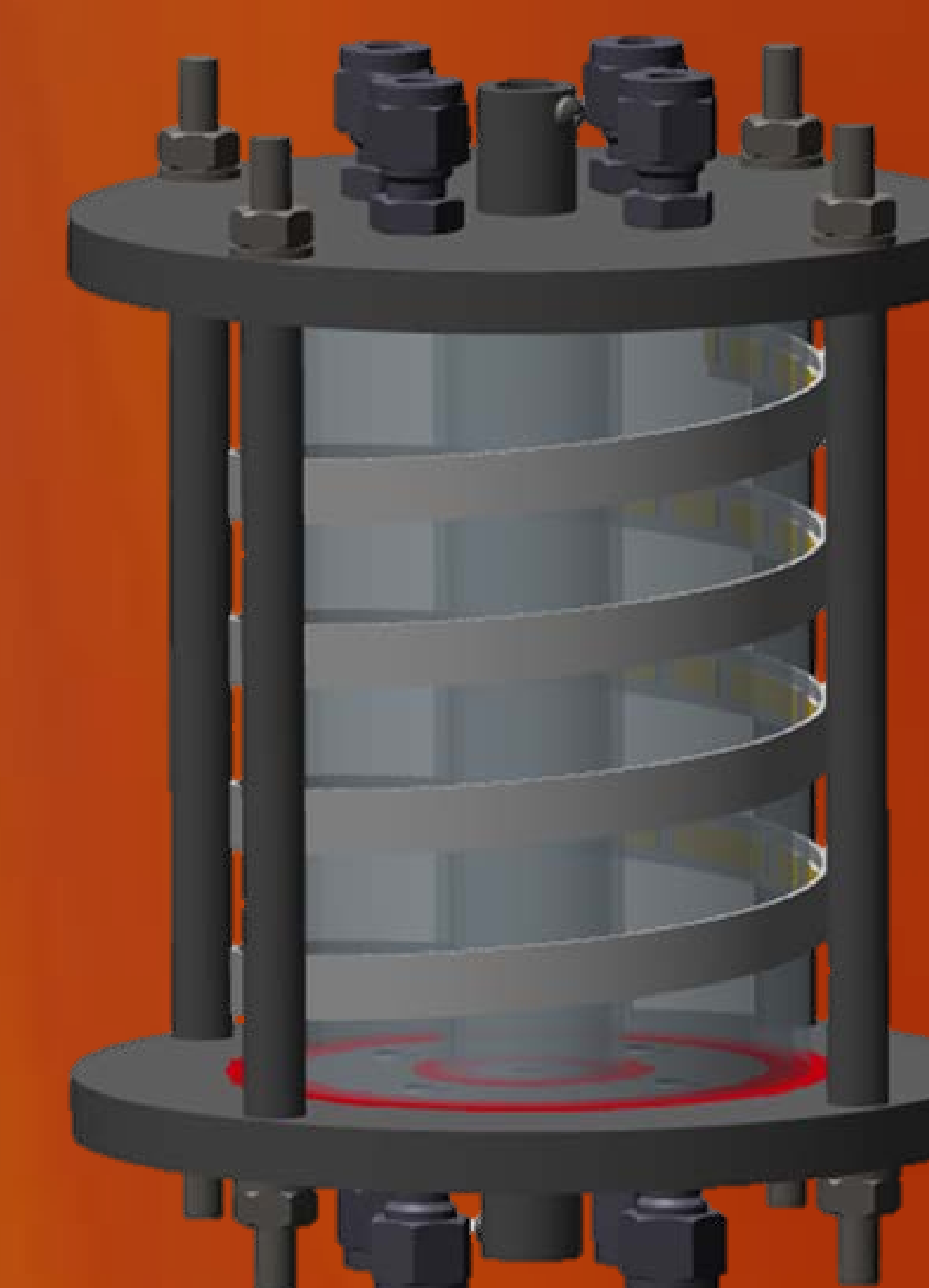
- Reactants are vaporized by incoming gas and high temperatures to react while suspended
- $$2\text{MoCl}_5 + 4\text{S} \rightarrow 2\text{MoS}_2 + 5\text{Cl}_2$$
- Resulting TMD deposits on downstream substrate

## Reactor System Design

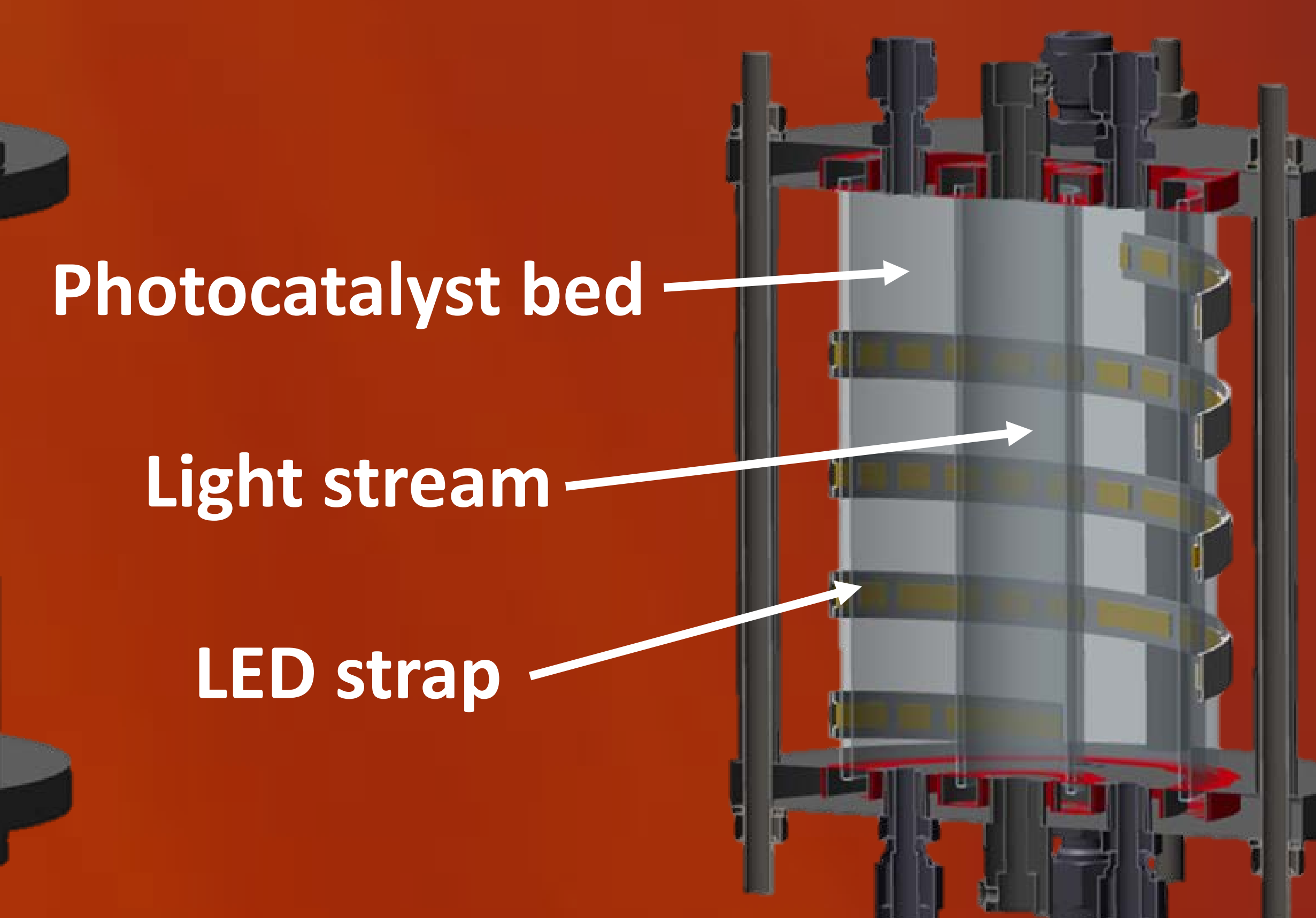
### Packed bed photoreactor

- TMD powders are supported on quartz wool and stored within the outer tube
- CO<sub>2</sub> is humidified with H<sub>2</sub>O and sent through reactor bed as a continuous flow
- Photocatalyst is radially exposed to UV light using a light stream in the inner tube and LED straps on the exterior shell
- Product gas will be analyzed with Gas Chromatography (GC) and Fourier Transform Infrared Spectroscopy (FTIR)

### Exterior view



### Cross-Sectional View



## Future Work

- Application of TMD powders supported on quartz wool in new reactor system with LEDs and solar simulator
- Improve CH<sub>4</sub> selectivity of TMD-based photocatalysts